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ANTICIPATED PROBLEMS AND PRELIMINARY EVALUATIONS OF EQUIPMENT TO BE USED IN PROTECTIVE SHELTERS

BY

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13 November 1964

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Port Hueneme, California

ANTICIPATED PROBLEMS AND PRELIMINARY EVALUATIONS OF EQUIPMENT TO BE USED IN PROTECTIVE SHELTERS

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Type C

by

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ABSTRACT

This report highlights a preliminary study on the anticipated problems associated with the use of standard, readily available equipment which may be used in protective shelters. The equipment under study consists of generators, air conditioners, air blowers, air filters, lighting fixtures, chemical toilets, and water pumps.

The problems that need further investigation and/or testing appear to be equipment shock tolerance, the overpressure effect on operating engines, equipment cooling, and equipment maintenance. Other problems include the possible contamination of shelter atmosphere with toxic gases generated by the equipment, equipment fire hazards, radio noise, and audible noise that may be generated by the equipment.

Suggested approaches to the solution of these problems are discussed and a general evaluation of equipment is given in tabular form.

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INTRODUCTION

The problems associated with equipment in protective shelters are twofold: those inherent in the equipment and those peculiar to the environment. The inherent problems with equipment are generally well known; however, they may be aggravated by the environment. The problems that are peculiar to the environment can be assumed or discovered experimentally only after the environment is defined and established. Since the requirements and function of protective shelters, other than to protect personnel and equipment from the effects of nuclear weapons, are as yet unspecified, the shelter environment must be assumed. It is anticipated that almost any emergency function might be performed in a shelter and that shelters will be designed for specific military or civilian functions. Shelters built to withstand overpressures up to 2000 psi have been considered. Capacities may range from less than 10 to more than 1000 persons. The duration of occupancy is generally stated as two weeks but could vary from a few hours to more than a month.

This report represents an attempt to define some of the problems with readily available equipment which may be used in protective shelters.

GENERAL SHELTER REQUIREMENTS

For a "survival only" type of shelter that provides for a minimum existence only, the requirements are quite different from those for a "functional" type shelter, such as a command post where the affairs of war will be conducted. Even in the case of the most austere "survival only" type of shelter, the minimum requirements have many contingencies and must be qualified. It must also be noted that the minimum requirements for a "survival only" type shelter may permit some psychological and physiological deterioration of the shelter occupants, while a "functional" type shelter must maintain personnel in operational condition.

Air Requirements

The minimum shelter air requirements of 3 cfm per person, given in Office of Civil Defense literature, should be considered an absolute minimum when persons are at rest and require fresh air to keep the

CO_2 content in the shelter atmosphere from becoming excessive. Cooling air and air required to purge the shelter of other noxious gases and air contaminants would be in addition to this 3 cfm per person. Reference 1 qualifies air requirements in this fashion:

a. In hot weather. 20 cfm of fresh air (refrigeration may be required) and 100 cubic feet of space per person.

b. In temperate weather. 10 cfm of fresh air and 70 cubic feet of space per person.

c. In cold weather. 7 cfm of fresh air and 50 cubic feet of space per person.

It must be remembered that these are minimum estimates for sedentary adults and do not account for the air required to cool shelter equipment, such as engine generators, electronic gear, lighting, and other items that may be used in functional type shelters.

Temperature Requirements

The maximum allowable effective temperature in any shelter should be 85 F (ET). Above 90 F (ET), the frequency of heat prostration increases rapidly, according to Reference 2.

Power Requirements

Shelter power requirements will, of course, depend upon lighting, ventilation, air refrigeration, and other electric and electronic gear installed in the shelter. An example of the probable minimum would be the 100-man shelter at the Naval Medical Center, Bethesda, Maryland, which requires about 4.5 kw of electric power with all electric equipment operating, which consists of about 800 watts of lighting, two electric cooking pots, and the air moving equipment.

The use of hand powered equipment in "survival only" shelters seems desirable when cost, maintenance, lack of noise, and physical exercise for shelter occupants are considered.

Lighting Requirements

Shelter lighting studies made by Sanders and Thomas for the Office of Civil Defense[3] indicate that levels of lighting as low as 1/2-foot candles are tolerable in "survival only" type shelters. However, it is conceivable that illumination levels of 50 foot candles will not be uncommon in a "functional" type shelter. An example of ample illumination is the 100-man shelter at the Naval Medical Center in Bethesda, Maryland, which is equipped with twelve 40 watt fluorescent lighting fixtures, which produce about 25 foot candles of illumination in the general living area and about 5 foot candles in the sleeping area. There are also three or four incandescent lamps in the entrance and toilet areas.

Overpressure Requirements

Overpressure requirements considered range from 0 psi for fallout shelters to 2000 psi for the hardened structures. The more common and practical range would probably be from 25 to 150 psi for which there are existing designs. The stated overpressure rating of existing shelter designs are contingent upon such factors as buried depth, soil conditions, soil compaction, etc. Shelters built to withstand 25 psi overpressure will afford adequate protection as close as 1/6-mile from a 1 KT burst or about 3 miles from a 10 MT burst. A 150 psi shelter is adequate at a minimum distance of about 350 feet from a 1 KT burst or about 1-1/4 mile from a 10 MT burst.

Shock Requirements

Studies made by E. J. Beck at the U. S. Naval Civil Engineering Laboratory[4] indicate that equipment which is hard mounted in a shelter, at a depth of 10 feet below the ground surface in the 25 psi region of a 1 KT weapon is likely to experience vertical and horizontal acceleration of about 11 G's, with displacements of less than 1/2-inch and velocities of less than 1 foot per second. If similar assumptions and the same methods of analysis are used, similarly mounted equipment, at a depth of 15 feet in the 150 psi overpressure region of a 10 MT weapon is expected to experience vertical and horizontal accelerations of about 50 G's, vertical displacements of about 19 inches, vertical velocities of about 4 feet per second, horizontal velocities of about 2.7 feet per second, and horizontal displacements of about 6.3 inches.

If equipment can be assumed to tolerate shocks up to 20 G's, it is apparent that some forms of shock attenuation must be employed, such as shock mounting or deeper burial, as discussed in Reference 4. Shocks of 5 G's are likely to cause injury to shelter personnel, according to Reference 4.

Noise Level Requirements

According to this author's interpretation of noise studies, discussed in References 5 and 6, the absolute maximum tolerable noise intensity levels in shelters should be about 80 db for extended periods of time (4 - 8 hours). Noise has both physiological and psychological effects on personnel. These effects are influenced by frequency, intensity, and time duration of the noise, and vary with the occupation of the personnel in the noise environment. According to Reference 5 (page 228), the maximum permissible sound intensity level in the sleeping areas of private homes is 25 db and this seems reasonable for shelter sleeping areas. Since voice communication is deemed necessary in shelters, a more practical maximum sound intensity level would be about 60 db in the general living area of a "survival only" type shelter. Long exposures to noise intensity levels above 85 to 95 db may cause loss of hearing and levels above 120 db can cause serious psychological or physiological illness in a relatively short time.

Thermal Radiation

Calculated values of thermal radiation, assuming clear atmospheric conditions, reveal that the 25 psi overpressure region of a 1 KT weapon yields about 30 to 40 calories per square centimeter, which is delivered in less than 1 second and the same region of a 10 MT weapon would be subjected to about 1000 calories per square centimeter delivered over a period of about 1 minute. Short exposures as low as 5 to 10 calories per square centimeter can ignite highly combustible fuels, such as newspapers, dry grass, or tree leaves, which create a hazard to support equipment located outside the shelter.

EQUIPMENT TYPES TO BE CONSIDERED

The types of equipment that are considered in this study are limited to those items which would normally be provided as a part of a construction contract and those which are directly related to essential utility services. They are: internal combustion, reciprocating type, engine driven generator sets; air conditioning equipment components; hand and electric powered air blowers; particulate air filters; lighting fixtures; chemical toilets, and hand and electric powered water pumps, both general purpose and deep well.

GENERAL EQUIPMENT REQUIREMENTS

The nature of nuclear threat requires that shelter equipment be maintained in a "ready for immediate use" condition for extended periods of time in an atmospheric environment which may be conducive to its deterioration. Equipment will be required to withstand shock in blast shelters. Equipment located external to the shelter may be required to withstand air drag, overpressure, thermal radiation, and electro-magnetic pulse, which may experience some attenuation when the equipment is buried.

PROBLEM AREAS

The anticipated problem areas are:

a. The deterioration of equipment which is kept ready for immediate use, arising from the necessary prolonged exposure of the equipment to the shelter atmosphere.

b. The deterioration of engine fuels and containers during long periods of storage.

c. Equipment damage from shock air drag, overpressure, thermal radiation, and the electromagnetic pulse.

d. The amount of heat energy added to the shelter environment by the operation of equipment.

e. The amount of radio noise generated by the equipment in shelters where communications are essential.

f. The potential fire hazards of equipment and fuels.

g. The amount of audible noise generated by the equipment.

POSSIBLE PROBLEM SOLUTIONS

The problem of equipment deterioration may be handled by the adoption of warehousing storage techniques where applicable, and establishing a routine maintenance program.

The fuel storage problem might be solved by using the more stable fuels, special storage procedures, periodic turnover of fuel supplies, or the development of specially treated or stabilized fuels.

Equipment damage from shock can be lessened by burying the shelters deeper, by shock mounting equipment, and by using the more shock-resistant equipment.

Air drag, overpressure and thermal radiation can be overcome by burying the equipment with the shelter or by using equipment that is most resistant to these forces.

Metal shielding of electrical equipment may give protection against voltage induction by the electromagnetic pulse.

Using equipment that has the highest efficiency will minimize the amount of heat energy added to the shelter. Special cooling techniques and locating equipment outside the main shelter may be the best solution to this problem.

Some types of equipment cause radio interference, but in most cases it is thought to be not a serious problem if radio shielding is used. Equipment that is inherently radio interference-free is the most desirable in shelters where communications are essential.

The potential dangers from noxious fumes and gases can be minimized by using engine fuels that are less volatile and/or less toxic and by using engines that tend to produce less toxic exhaust products. Locating equipment outside the shelter and away from shelter air inlets is also a possible solution. Ozone production can be minimized by using non-sparking electrical equipment. Noxious sewer gases can be minimized by proper ventilation system design or by using activated charcoal filters or toilet vents. Shelter design is an important factor in solving these problems.

Fire hazards can be minimized by using equipment that does not require highly flammable fuel, careful maintenance, using non-sparking electrical equipment, or by the isolation of this type equipment in the shelter design.

The problem of audible noise varies somewhat with the type of equipment used, but is probably best solved by noise isolation devices and shelter design.

EVALUATION OF EQUIPMENT TYPES

Tables I through VI give a subjective evaluation of equipment types that may be used in nuclear bomb shelters. This evaluation is based upon present state of the art knowledge about shelter environments and functions, and should be used only as a very general guideline. Equipment characteristics are plotted against location and type. The higher numbers indicate better ratings and are not given where information is yet to be determined.

Generator Engines

In reviewing generator engine ratings in Table III, it will be noted that the highest rating has been given to the air cooled diesel engine. The advantages of this type of engine are:

a. They use the safest available fuel from the standpoint of fire hazard.

b. They use a fuel that has about twice the storage life of gasoline. (Ordinarily, diesel fuel can be stored for periods not exceeding one year.)

c. They use a fuel that does not generate noxious fumes at ambient temperature as gasoline does. (Gasoline vapors are toxic in relatively small concentrations and are mostly heavier than air.)

d. They use a fuel which requires the smallest comparable volumetric storage capacity of all of the fuels considered.

e. The fuel storage container need not be pressurized as liquified petroleum gases (LPG) or natural gas which would be exceedingly difficult to store due to pressure and volume requirements.

f. The typical exhaust gases of a properly adjusted normally operating diesel engine are considerably less toxic than a comparable gasoline engine.

g. The engine-generator cooling system may require considerably less cooling air than a comparable liquid cooled unit that is radiator cooled.

h. They use a cooling system which requires a minimum of maintenance, will not freeze, and is less likely to be seriously damaged by shock, overpressure, or flying missiles.

i. The size and weight of an air-cooled unit is generally less than that of a comparable liquid cooled unit, thereby allowing for easier installation in shelters.

j. The diesel compression ignition type engine appears to be more resistant to damage from thermal radiation, which may burn the exposed ignition system wiring of spark ignition engines.

The disadvantages of the air-cooled diesel engine are:

a. They are not as readily available as gasoline or liquid cooled units.

b. They are not domestically manufactured in sizes above 10 KW.

c. They are more expensive than most comparable gasoline sets, but less expensive than liquid cooled diesels.

d. They are generally slightly larger and heavier than air-cooled gasoline engines.

e. They are probably not as reliable as spark ignition engines equipped to burn LPG or natural gas and, therefore, may require more maintenance.

f. Diesel fuels generally cannot be stored for indefinite periods as can LPG or natural gases.

g. Diesel engines and particularly air-cooled engines are generally more noisy than spark ignition engines; however, this is probably more a function of engine design than type. A typical diesel engine generator set may emit noise at an intensity level of about 100 db, but may be reduced by the use of special mufflers.

h. Air-cooled engines do not lend themselves to remote cooling. However, remote cooling of the engine does not eliminate cooling air required by the generator, which must not be neglected.

Areas of further interest for engines operating shelter support equipment are:

a. The exhaust products of spark ignition engines fueled with kerosene, LPG, or natural gas.

b. The overpressure effect on operating engines.

c. Transient thermal radiation effects on engines and engine-generator housings.

d. Engine noise.

e. Shock tolerance of operating engines.

f. Engine generator cooling techniques.

Generators

The brushless generator has been rated highest among the four types considered. (See Table V) Its advantages may be determined by reviewing Table IV. Areas of further interest for generators are similar to those for generator engines.

Lighting Fixtures

The evaluation of shelter lighting is more difficult than other items. Generally, the larger shelters that require high intensity lighting should be equipped with fluorescent light fixtures and the smaller shelters, that require low level lighting, should use incandescent lamps. Lighting fixtures should be tested for mechanical shock tolerance.

Air Conditioning Equipment

Air refrigeration in shelters is expected to consist of readily available components adapted to shelter use by the shelter designer since applicable packaged units are not available. Shock tolerance and toxicity of the refrigerant appear to be the chief problems inside shelters. Overpressure and thermal radiation must be considered when locating components outside of protected areas. The equipment room appears to be a good location for the compressor when considering compressor noise and heating.

Air Blowers

Air blowers are not expected to present any particular problems if used in shelters; however, they should be tested for shock tolerance. The shelter designer must give adequate consideration to capacity, static pressure, and blower noise, which are all related to blower design.

Air Filters

Commercially available air filters have been tested at this Laboratory.[7] These filters, however, do not guarantee absolute protection against radiological and bacteriological attack and should be used only as a prefilter in series with an absolute type filter capable of removing 99.97 per cent of the particles 0.3 microns and larger.

Chemical Toilets

In shelters where displacements may be appreciable due to ground shock, chemical toilets equipped with tanks that may be mounted directly on the shelter floor appear preferable to the built-in type with tanks installed below the floor. Care should be exercised in proper venting of toilets because of the possibility of contaminating shelter areas with combustible and highly toxic sewer gases.

Water Pumps

Water pumps appear to present no significant problems when used in shelters, but design considerations should be given to pump shock tolerance and audible noise.

Deep Well Pumps

Deep well pumps may experience casing fractures in areas where ground displacements are appreciable unless special techniques of protection are used. (See Reference 4, Figure 19.)

CONCLUSIONS

The following conclusions are a result of the foregoing study.

1. Diesel engine driven generator sets are the most desirable for use in shelters.

2. Air cooled engines are more desirable for shelter use than liquid cooled units.

3. All equipment should be installed in areas that are protected from overpressures, thermal radiation and shock, in an area that is isolated but accessible to shelter personnel.

4. Brushless generators are more desirable for shelter use than other types.

SUGGESTED TEST PROGRAM

To further evaluate equipment that may be used in a shelter environment, it is suggested that the following tests be performed:

1. Test at least one diesel engine driven generator set for the effect of overpressure on the internal parts of an operating engine. This would involve subjecting the engine's air intake and exhaust duct to an overpressure wave generated by the NCEL blast simulator. The planned procedure would establish the first overpressure wave at about 5 psi and increasing in increments of about 5 psi until an indication of the reaction of the engine can be determined.

2. Perform shock tests on small generator sets, pumps, lighting fixtures, air blowers, and air conditioning equipment components. These items should be tested, starting with loads of about 5 G's and increasing in 5 G increments until failure occurs. Available shock test facilities are located at the Naval Missile Center, Point Mugu, California.

RECOMMENDATIONS

The following recommendations would be helpful in establishing equipment requirements for shelters:

1. Initiate the suggested test program outlined above.

2. Investigate maintenance requirements associated with equipment and fuels that may be kept in shelters for long periods of time.

3. Where possible, more definitive shelter and equipment requirements for other than "survival only" type shelters should be established.

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Table I. Generator engine evaluation.

Engine Characteristic \ Engine Type	Liquid Cooled Natural Gas	Liquid Cooled LP Gas	Liquid Cooled Kerosene	Liquid Cooled Gasoline	Liquid Cooled Diesel	Air Cooled Natural Gas	Air Cooled LP Gas	Air Cooled Kerosene	Air Cooled Gasoline	Air Cooled Diesel
Reliability	8	8	7	7	7	9	9	8	8	8
Maintenance Requirements	5	5	4	4	5	6	6	5	5	6
Fuel Storage	0	5	3	2	3	0	5	3	2	3
Fire Hazard	1	0	7	0	9	1	0	7	0	9
Noxious Gases				1	7				1	7
Installation	3	4	2	4	3	4	5	3	5	4
Cooling	2	2	2	2	2	9	9	9	9	9
Overpressure										
Shock										
Thermal Radiation										
Audible Noise										
Radio Noise	1	1	1	1	2	1	1	1	1	2

Table II. Generator engine location influence on characteristic.

Engine Characteristic \ Engine Location	Equipment Room	Main Shelter	Pit Located	Surface Located
Reliability	7	7	4	5
Maintenance Requirements	8	8	4	5
Fuel Storage	4	4	6	9
Fire Hazard	2	1	8	9
Noxious Gases	3	1	9	9
Installation	1	2	7	9
Cooling	2	2	7	9
Overpressure	9	9	1	1
Shock	6	6	5	3
Thermal Radiation	9	9	2	1
Audible Noise	6	1	9	9
Radio Noise	7	6	5	4

Table III. Generator engine ratings.

Equipment Room	Main Shelter	Pit Located	Surface Located	Engine Type
9	9	9	9	Air Cooled Diesel
5	4	7	7	Air Cooled Gasoline
7	7	8	8	Air Cooled Kerosene
6	5	8	8	Air Cooled LP Gas
6	5	8	8	Air Cooled Natural Gas
7	7	7	7	Liquid Cooled Diesel
4	3	5	5	Liquid Cooled Gasoline
5	5	6	6	Liquid Cooled Kerosene
5	4	6	6	Liquid Cooled LP Gas
5	4	6	6	Liquid Cooled Natural Gas

Table IV. Generator evaluation.

Generator Characteristic \ Generator Type	Permanent Magnet	Revolving Field	Revolving Armature	Brushless
Reliability	9	8	7	9
Maintenance Requirements	5	4	3	5
Fire Hazard	9	4	4	9
Noxious Gases	5	4	3	5
Installation	5	4	5	4
Cooling	5	5	5	5
Overpressure				
Shock				
Thermal Radiation				
Audible Noise				
Radio Noise	3	2	1	3
Voltage Control	1	5	4	5

Table V. Generator ratings.

Generator Type \ Generator Location	Equipment Room	Main Shelter	Pit Located	Surface Located
Brushless	9	9	9	9
Revolving Armature	6	6	6	6
Revolving Field	7	7	7	7
Permanent Magnet	8	8	8	8

Table VI. Light source evaluation.

Lamp Characteristic \ Light Source	Mercury Vapor	Fluorescent	Incandescent
Reliability	9	9	9
Maintenance	9	9	9
Heat Load	9	9	4
Installation	7	7	9
Shock			
Radio Noise	5	5	9
Starting	4	8	9
Color Distortion	3	8	8
Voltage Sensitivity	6	8	9

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13. ABSTRACT

This report highlights a preliminary study on the anticipated problems associated with the use of standard, readily available equipment which may be used in protective shelters. The equipment under study consists of generators, air conditioners, air blowers, air filters, lighting fixtures, chemical toilets, and water pumps.

The problems that need further investigation and/or testing appear to be equipment shock tolerance, the overpressure effect on operating engines, equipment cooling, and equipment maintenance. Other problems include the possible contamination of shelter atmosphere with toxic gases generated by the equipment, equipment fire hazards, radio noise, and audible noise that may be generated by the equipment.

Suggested approaches to the solution of these problems are discussed and a general evaluation of equipment is given in tabular form.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Generators	9					
Air Conditioners	9					
Blowers	9					
Air Filters	9					
Lighting Fixtures	9					
Chemical Toilets	9					
Water Pumps	9					
Shelters	5					
Problems	8					

INSTRUCTIONS

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